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COMPOSITIONAL VARIABILITY OF THE MARTIAN SURFACE.

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We analyzed spectral reflectance data from Viking Landers and Orbiters and from telescopic observations, with the objective of isolating compositional information about the Martian surface and assessing compositional variability. Two approaches were used to calibrate the data to reflectance to permit direct comparisons with laboratory reference spectra of well characterized materials (1-7). In Viking Lander multispectral images (six spectral bands) most of the spectral variation is caused by changes in lighting geometry within individual scenes, from scene to scene and over time. Lighting variations are both wavelength independent and wavelength dependent (1). By calibrating Lander image radiance values to reflectance using spectral mixture analysis (1) we assessed the possible range of compositions with reference to a collection of laboratory samples, also resampled to the Lander spectral bands. All spectra from the Lander images studied plot (in 6-space) within a planar triangle having at the apexes the respective spectra of tan basaltic palagonite, gray basalt and shade. Within this plane all Lander spectra fit as mixtures of these three endmembers; therefore, pure materials that occupy this space cannot be distinguished mixtures of these endmembers. Reference spectra that plot outside of the triangle are unable to account for the spectral variation observed in the images.

In earlier work (1) we concluded that the rocks at the Lander sites could be unweathered basalts or andesites, and that both oxidized and unweathered basaltic fines were present. Laboratory spectra of many basalts and andesites appear similar when sampled with the six Lander bands. The main difference between the two rock groups is that the basalts typically are darker than the andesites. Otherwise, both rock types are spectrally similar, having nearly equal reflectances at all wavelengths ("gray"). If andesitic rocks occur on Mars there also should be andesitic tephra, which, unaltered, has a substantially higher albedo than basaltic tephra. Accordingly, we searched Lander images for gray, moderate albedo rocks and for a light gray component of the fines. In addition, we postulated that aeolian abrasion might produce finely particulate crystalline basalt (unweathered) that would be expected to have a spectrum close to that of andesitic tephra.

Fig. 1 shows the endmember triangle on the plane defined by Lander bands 1 and 3, and illustrates that a small portion of the data encompasses andesites, andesitic tephra, and mixtures of basalt and crystalline basalt powder, giving the impression that these or spectrally similar materials are present in the Lander images and mix with the other spectral endmembers. However, when each spectrum is traced back to the image, the context reveals that this gray "component" always coincides with a specular lighting geometry. To compare image and laboratory spectra the lighting geometries of the measurements must be approximately the same. Bidirectional and total hemispherical laboratory measurements avoid specular reflections, because for most silicates they introduce a "gray" component that increases the overall lightness and reduces spectral contrast. Many Lander images, however, include local areas (especially on dust-free rocks) that have specular (or quasi-specular) reflection from surfaces that are oriented appropriately relative to the sun and the camera. These specular reflections, which occur at both pixel and sub-pixel scales, plot outside the basaltic spectral endmember plane, coincident with the spectra of andesitic materials and their mixtures with the basaltic materials. The specular reflections disappear when the same areas are imaged under different lighting conditions. Thus, there is no spectral evidence for an andesitic or other spectrally similar components at the Lander sites.

A Viking Orbiter image (3 bands) was analyzed of the Chryse Planitia - Kasei Valles - Lunae Planum region that includes the Lander 1 site. The calibrated spectra plot within the central part of the mixing triangle defined by the Lander data, indicating that these Orbiter pixels are consistent with mixtures of the Lander endmembers, and that the reference spectra (basaltic palagonite, basalt and shade) account for the spectral variation at a regional scale. The three broad Orbiter bands, although of limited use for identifying most materials, are sufficient to distinguish a light achromatic component. This component was not detected, therefore, we detected no areas of pure andesite or andesitic tephra, or mixtures of these materials with the modeled basaltic materials. The basaltic reference spectra also fit the spectral variation in 1969, 1973 and 1978 telescopic spectra.

The spectral detectability of andesite or of any other material on Mars depends on several factors, including the spectral contrast between the material and its background, the spectral and spatial resolution, and the signal-to-noise of the data. Although a few percent of andesitic materials cannot be ruled out, and other Orbiter

images and telescopic spectra remain to be analyzed, all of the spectral data examined so far fit the model of the Martian surface consisting primarily of basaltic rocks, unweathered basaltic fines, and chemically weathered basaltic fines.

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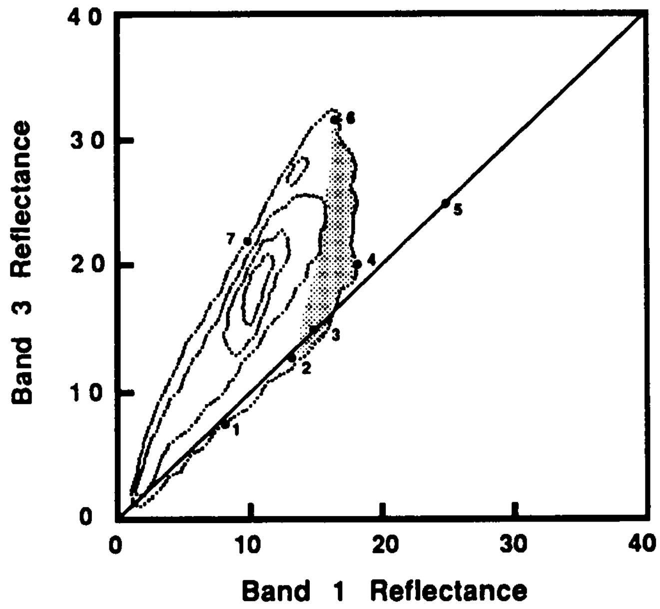

Figure 1. Histogram of six-band spectra from a Viking Lander image (VL1-28) displayed on the two-dimensional plane of bands 1 (blue) and 3 (red). Units are in percent reflectance. Contours show increasing number of pixels toward a maximum near blue = 10, red = 20. Laboratory reference spectra, resampled by the Lander bands, are plotted as filled circles. Basalt tephra (1), basaltic rocks (2), andesitic rocks (3), andesitic tephra (4), and basaltic rock powder (5) plot on or near the achromatic line (blue = red). The stippled region corresponds to specular reflections from a few (mostly rock) surfaces in the image. Basaltic rock (2), fine-grained weathered basaltic palagonite (6) and mixed grain-size basaltic palagonite (7) along with shade (blue = 0, red = 0) model the non-specular parts of the image.